PRESENTACIÓN MURAL

Southern near-infrared photometric monitoring of Galactic young star clusters (*NIP of Stars*)

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Abstract. We have performed a near-infrared photometric monitoring of 39 galactic young star clusters and star-forming regions, known as *NIP of Stars*, between the years 2009–2011, using the Swope telescope at Las Campanas Observatory (Chile) and the RetroCam camera. The primary objective of the campaign is to perform a census of photometric variability of such clusters and to discover massive eclipsing binary stars. In this work, we describe the general idea, the implementation of the survey, and the first preliminary results of some of the observed clusters. This monitoring program is complementary to the *Vista Variables in the Vía Láctea* (*VVV*), as the brightest sources observed in *NIP of Stars* are saturated in *VVV*.

Resumen. Hemos realizado un monitoreo fotométrico infrarrojo de 39 cúmulos jóvenes y regiones de formación estelar galácticas, conocido como *NIP of Stars*, entre 2009–2011, utilizando el telescopio Swope del Observatorio las Campanas (Chile) y la cámara RetroCam. El objetivo primario de la campaña es hacer un censo de variabilidad fotométrica de tales cúmulos, y descubrir binarias masivas eclipsantes. En este trabajo presentamos la idea general del proyecto la implementación de un datoducto semiautomático, como así también resultados preliminares en uno de los cúmulos observados. Este programa de monitoreo es complementario al relevamiento *Vista Variables in the Vía Láctea* (*VVV*), dado que las fuentes más brillantes observadas en *NIP of Stars* saturan en *VVV*.

1. Motivation and sample selection

The mass, mass-loss and rotation are among the most important parameters that govern the stellar evolution. In the context of stellar masses, massive O and WR-type binaries are key objects because they enable us to determine min-

imum masses from the solution of their radial-velocity (RV) curves, and in the case to constrain the orbital inclination (for example through eclipsing binaries), we can get absolute masses. Knowing the multiplicity of massive stars is important because this factor has a deep impact on stellar evolution, the initial mass function, and on the energy balance of its environment and helping with clues about their origins (Zinnecker & Yorke, 2007).

The ample majority of studies about massive eclipsing binaries comes from observations in the optical range, therefore the sample is limited to very few objects with relatively low reddening. Surprising to learn that of the 370 O-type stars which are counted in the *The Galactic O Star Catalog* (*GOS*, Maíz Apellániz et al. 2004), there are only 38 eclipsing or ellipsoidal variables. From this group, no more than fifteen systems have reliable light- and RV- curves. The panorama resulting in the infrared is much worse: there are only five massive eclipsing systems with published data. Conclusion: all our knowledge about the absolute masses of massive stars of O- and WN-type is derived from only few tens of objects. A situation which poses challenges.

The primary objective of this project is to conduct a census of photometric variability in a set of young galactic open clusters and star forming regions affected by large extinction ($A_V = 6 - 30$). From those variable stars, we are specially interested in the massive eclipsing binaries, which can be observed spectroscopically to determine absolute stellar parameters. We have selected thirty-nine galactic young clusters and star-forming regions following these criteria: a) clusters must be more or less resolved at scale of one arcsecond, with uncrowded background to get reliable photometry. Thus, clusters like Arches are discarded; b) some of its massive members must have spectral classification; c) previous studies must have indication of the presence of at least five stars with spectral type earlier than B0; d) such stars must be in the H-magnitude range $8 < H < 12$.

This NIR photometric monitoring program is very complementary to the *Vista Variable in the Vía Láctea* (*VVV*, Minniti et al. 2010) survey, as the brightest sources of *NIP of Stars* are saturated in *VVV* images.

2.   Observing campaigns and pipeline

The observations were carried out using the RetroCam camera attached to the Swope 1-meter telescope at Las Campanas Observatory (Chile) during three seasons in 2009 to 2011. Thirty-eight observing nights presented photometric conditions, from a total of seventy-three nights. Ten nights were completely lost due to bad weather. The RetroCam camera (Hamuy et al. 2006) consists of an one-megapixel Rockwell Hawaii-1 HgCdTe array, with a spatial scale of $0\farcs54$ per pixel, which provides a $9' \times 9'$ field-of-view (FOV). This spatial resolution is about four times better than Two-Micron All Sky Survey images (*2MASS*, Cutri et al. 2003). The monitoring campaign was performed preferentially in the H_C filter, and occasionally in J_S and Y_C, as this camera does not have K-band filter.

For the reduction of hundreds of thousands of observations, we have implemented a semi-automated pipeline, which is based in part on the procedures used in the *Carnegie Supernova Project* (*CSP*, Hamuy et al. 2006). The requirements of our project are much more severe than *CSP* in terms of background
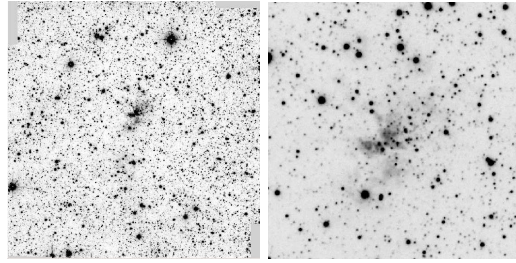
Figure 1. Left. RetroCam H_C image of the star-forming region IRAS 16177–5018 obtained in July 2009, the FOV is about $10'$. This is an example of an infrared cluster with relatively uncrowded background. Right: the core of this cluster.

subtraction in areas with high-density of stars and very bright nebulosities. The pipeline is based on a series of *IRAF* scripts, shell scripts in *gawk*, *FORTRAN* code, and makes use of *SExtractor* code (Bertin & Arnouts, 1996). Furthermore, it is structured in *Python* programming language. In a second stage, we plan to obtain astrometric solutions using *Swarp* and *Scamp* codes (Bertin, 2006), and the photometric zero-points using *2MASS* and *VVV* surveys. Reduced images and metadata are being stored in a database managed by *MySQL*. Figure 1 shows an example of H_C images.

3. First steps in the photometric analysis

In a first stage, we are performing aperture photometry of a small set of objects in order to check the photometric stability of observations. From this process we are getting excellent results, which guarantee relative errors comparable to those obtained using well exposed CCD images in the optical range.

Figure 2 shows some results of the differential photometry for five H_C mosaics of the young clusters Danks 1 and 2. This differential photometry is relative to a H_C mosaic used as reference image. A mean-σ of 0.02 mag is obtained for the instrumental magnitude difference for twenty images of Danks 1 and 2, in the range $14 - 16$ mag (S/N> 200). Thus, about 5% of the sources show variability greater than 2σ: these stars are potential variables. After this stage of photometric characterization of the sample, we plan to design a pipeline to perform automated *point-spread-function* photometry and we will start to test the *image-subtraction algorithm*, (Alard & Lupton, 1998).

As a pilot case, we have observed the massive eclipsing binary FO15 (O5.5 V + O9 V, $P = 1.41$d) in the Carina Nebula, with the aim to evaluate the quality of the differential photometry procedures. Figure 3 shows the phased light-curve of FO15 in the Y_C band, which can be compared with that published by Niemela et al. (2006) using optical *All-Sky Automated Survey* (*ASAS*) (Pojmański 2003) observations. In spite of the fact that aperture photometry of FO15 was done without the appropriate photometric calibrations, it is clear the superior quality of the NIR light-curve.
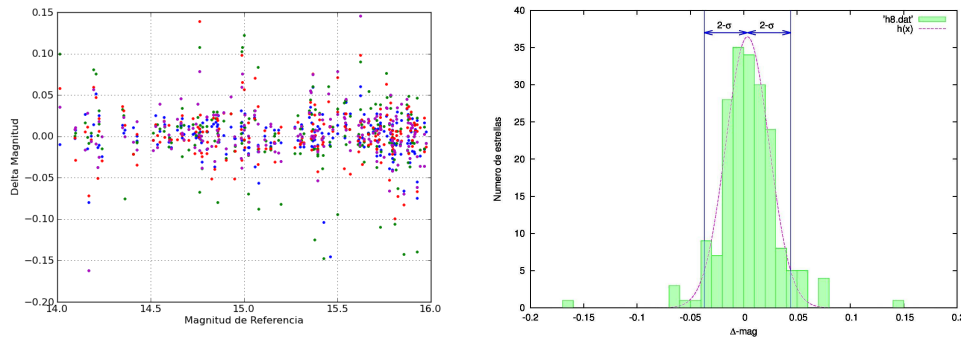
Figure 2.   Left: differential instrumental magnitude for five H_C mosaics of Danks 1 and 2 clusters respect to a reference mosaic. The typical σ for each star is about 0.02 mag. Sources with $\Delta H_C > 2\sigma$ are potential variables. Right: distribution of σ (green histogram) for the differential photometry of twenty H_C images of the same clusters. Variable star candidates are those beyond the 2σ interval. The fitted curve (in red) correspond to a Gaussian function with $\sigma = 0.020$.
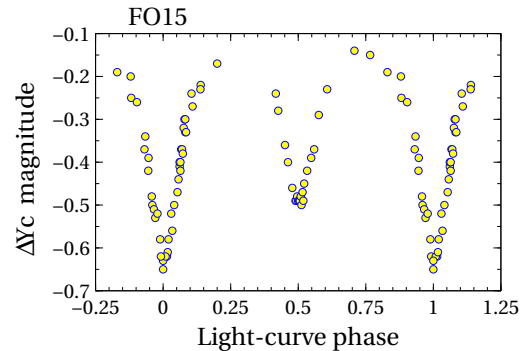

Figure 3.   Near-infrared light-curve of the massive eclipsing binary FO15 in the Carina Nebula. The photometric data were phased using the ephemeris published by Niemela et al. (2006).

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